Intellectual Mastery of Nature: Theoretical Physics from Ohm to Einstein. Vol. 1, **The Torch of Mathematics 1800–1870** ($55.00); Vol. 2, **The Now Mighty Theoretical Physics 1870–1925** ($65.00). By Christa Jungnickel and Russell McCormmach. Chicago (University of Chicago Press). 1986. xxiii + 350; xii + 435 pp.

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These two volumes by Jungnickel and McCormmach (cited henceforth as J&M) are of central importance for the study of 19th-century physics. All historians of science interested in this period will henceforth have to consult this work before and during their research for it contains such a wealth of information that it can be ignored only at great scholarly peril. At the same time, however, readers should be aware of some serious flaws that make parts of it untrustworthy and misleading.

The cardinal virtue of this work rests on the treasure-trove of archival documents that J&M have discovered and exploited. They have systematically examined the documents relating to the teaching of physics in the German universities in the 19th and early 20th centuries. From these documents, they are able to give a detailed and rich picture of the institutional and social conditions in which German physics grew and developed. This part of their work is superb. Here the reader will find all one could ever wish to know about internal academic politics and its relationship to the teaching of physics; the funding of positions in physics; the attempts to squeeze out extra funds from governmental ministries whose knowledge and interest in physics was minimal; and all those other aspects of academic life that remain with us today. The reader will also find a rich description of the facilities for doing research in physics, of the founding and development of institutes of physics, so central to the development of both experimental and theoretical physics in Germany in the 19th century. There are even detailed accounts of the instruments available and bibliographical references permitting the reader to follow up the instrumental dimension. There is nothing else comparable to this work available today and it will, therefore, occupy the central position it deserves in the literature. One fundamental question did suggest itself, however, which J&M never address: given the well-documented fact that German physics constantly confronted local and ministerial financial and intellectual obstacles, how did the *Naturwissenschaftswunder* that is 19th-century physics ever occur? The authors never raise this question.

J&M however, aim at more than setting the institutional, political, and instrumental scene within which theoretical physics developed. As they say in the preface to Volume 1, "The goal of our study of German theoretical physics is to give an integrated account of the scientific work and its institutional setting" (p. xviii). And, further, "of equal importance to our study as the physicists' institu-

tional activities is their scientific work," but they "do not give a complete and continuous history of their work since many studies have set out to do just that . . ." (p. xviii). It is this further goal of placing the *work* of theoretical physicists into the institutional context that leads to the more serious flaws. Let me detail them.

Confusion begins at the start of Volume 1. What is theoretical physics? To be sure, no historically exact definition can be given for 1800, since the very concept did not really exist at this point. Nevertheless, it is possible to differentiate styles of physics that could all be considered as "theoretical physics" before the time of Ohm. Simply put, shall we consider theoretical physics to be the application of mathematics to experimental facts to determine a mathematical law? This would make experiment primary and mathematics the servant of the experimentalist. Or, should the theoretical physicist emulate Poisson, make some simple assumptions about the forces acting between electrical fluids, and then derive the equations for the distribution of electricity on the surfaces of bodies of different shapes by pure mathematics? It then becomes the task of the experimentalist to determine the validity of the derivation. Here theoretical physics leads and experiment follows. Or, finally, should the theoretical physicist occupy himself with the hidden *causes* of physical phenomena, that is, should he make up theoretical or noumenal entities and then derive phenomenal laws from their assumed properties? All three of these approaches are described by J&M, but without comment. Thus, Kirchhoff's "aim was to build equations that correspond to the phenomenal world as accurately as possible and with as little dependence as possible on anything hypothetical" (p. 294). Gauss is quoted in Poissonian mode (p. 139), "I cannot formulate any idea of the cause of Volta's fundamental theorem: in the event of the participation of molecular forces, one might be able to think of something that is accessible to calculation." Neumann offers an orthodox Kantian view for, to Neumann, "to 'explain' is to reduce phenomena to the 'fewest possible fundamental ideas', which are themselves inexplicable, or 'incomprehensible'" (p. 183).

This failure to distinguish between the possible approaches to theoretical physics creates a good deal of confusion, particularly in Volume 1. What is inexplicable is that it was clearly avoidable, for Kenneth Caneva has raised the problem quite specifically. In his 1975 Princeton dissertation, Caneva devoted almost 150 pages to a discussion of the varieties of theoretical physics aborning in early 19th-century Germany. A more sophisticated and fully documented version of his thesis was published in 1978 in *Historical Studies in the Physical Sciences*, a journal of which McCormmach is an editor. Yet, surprisingly, neither of these works is either cited or mentioned, although the journal article appears in the bibliography. This failure is a symptom of a deeper problem for the authors also fail to follow Caneva in discussing the influence of German philosophy on German physics. This is a truly fatal error for it robs their discussion of an essential dimension. Stated quite baldly, German physics and German philosophy were tightly bound together through most of the 19th century.

J&M barely mention philosophy. "Almost to a man," they write on p. 23, "the German university physicists declared themselves influenced by his [Kant's]

work." This is followed by a single paragraph that hardly does justice to Kantian philosophy and leaves the reader completely at sea unless he is already well acquainted with Kant's works. Nor is Kant the only philosopher. Again, as Caneva made clear, Schelling, Fichte, and Schleiermacher all influenced some of those whom J&M characterize as prototheoretical physicists.

The failure to deal with the philosophical background to theoretical physics, together with the very brief accounts of the science actually done by theoretical physicists (only some 40 pages out of 350 in Volume 1), vitiates the attempt to deal adequately with their chosen examples. Few, if any, of the short biographies here equal or go beyond those to be found in the *Dictionary of Scientific Biography*. Sometimes, the authors do add documents from their new findings that will be found useful, but they do not always apply them well. Again, part of the fault lies with their blindness to philosophy. Take the example of Ludwig Boltzmann, who served at least partially as a model for the hero of McCormmach's novel on the *Night Thoughts of a Classical Physicist*. (For what follows, I am completely indebted to my student, Andrew Wilson, who has just returned from Vienna where he delved into the Boltzmann manuscript *Nachlass*.) A minor, but confidence-destroying, fault is that the attribution to the Boltzmann manuscripts J&M cite is incorrect. They are not in the Österreichisches Staatsarchiv, Wien (described on p. 199 of Volume 2 as their "final home") but in the Allgemeines Verwaltungsarchiv, undoubtedly moved there by the Austrian bureaucracy after they were consulted by J&M. One ought not to attribute anything *final* to any bureaucracy.

J&M describe Boltzmann's university training by stating simply that he studied with Kunzek and Ettingshausen as well as with Lang and Stefan. This is true, but it is also misleading. Out of a total of 162 hours taken by Boltzmann in the years from 1863 to 1867, 16 were with Kunzek, 32 (of which 30 were laboratory courses) with Ettingshausen, 22 with Stefan, and 4 with Lang. What J&M ignore is 24 hours of Analytical Mechanics with Petzval (which clearly influenced Boltzmann's later work) and 21 hours with the philosopher Zimmermann whose books were heavily annotated by Boltzmann. Surely Petzval and Zimmermann deserve at least a passing glance to determine if their influence might, indeed, permit us to understand Boltzmann's work better.

This one example may be atypical, but it caused me some concern about the way in which J&M read the rich manuscript vein they have uncovered. No one can follow their footsteps to check every source, but it is perhaps fair to suggest that their sources not be accepted without question.

Let us now sum up. I repeat that this work is essential and that it contains much that is of great value to historians of modern physics. My criticisms, however, should indicate that the work should be used with some caution and readers should be aware that the picture that is presented is two-dimensional. The philosophical aspects remain to be investigated, and they are of basic importance. Finally, the mini-biographies add little new or original information to what J&M have to say. In fact, had they omitted them and simply referred readers to the *DSB* they could probably have accomplished their goal in one volume at considerably

less expense to the reader. The work could then have borne the more accurate, although less rhetorical title, *The Growth of the German Physical Community, 1800–1925*.

Philosophie als Analysis: Studien zur Entwicklung philosophischer Analysiskonzeptionen unter den Einfluss mathematischer Methoden-Modelle im 17. und frühen 18. Jahrhundert. By Hans-Jürgen Engfer. Forschungen und Materialien zur deutschen Aufklärung (Series 2, Vol. 1). Stuttgart—Bad Cannstatt (Fromman-Holzboog). 1982. 293 pp. $50.00.

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Hans-Jürgen Engfer investigates the influence of the methods of mathematics upon (1) the continental European analytical tradition within rationalism during the 17th and early 18th centuries and (2) the German *Aufklärung* during the second half of the 18th century. The section on the earlier period examines the methodologies of Descartes, Leibniz, and Wolff. The late *Aufklärung* section examines three prize competitions on methodology sponsored by the Berlin Academy of Sciences (1763, 1805, and 1809) and the emergence of the "critical" philosophy of Kant.

Engfer's topic is central to understanding the Enlightenment, in which reason was considered the key to method, and mathematics provided for many the ideal for reasoning. Mathematics had its own methods of synthesis and analysis. During the Enlightenment, "synthesis" referred to Euclid's axiomatic method, and "analysis" largely referred to symbolic algebra and the new infinitesimal calculus. Because of its chronological limits, this book obviously does not deal with the mature stage of mathematical analysis of Cauchy, Weierstrass, Dedekind, and Cantor.

This book begins in reverse chronological order with the Berlin Academy of Sciences' prize competition on methodology in 1763. The question posed was whether metaphysical truths can be established with the same degree of certainty as those of geometry. The philosopher Moses Mendelssohn, who is known as the "German Socrates," won the prize. His paper asserted that the proper method for a complete system of truths "is not the synthetic . . . but the analytic." Immanuel Kant agreed in his prize paper the next year and began to distinguish between the methods of mathematics and of metaphysics. Kant corresponded with Johann Lambert on these matters. An intense period of reform of analytic concepts and methods followed. Concern with analytic methods in philosophy remained central at the Berlin Academy through its prize competitions on the subject in 1805 and 1809.